

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



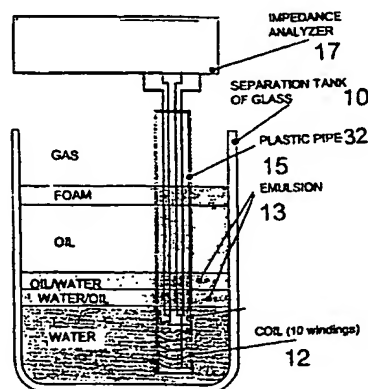
(43) International Publication Date  
1 February 2001 (01.02.2001)

PCT

(10) International Publication Number  
**WO 01/07874 A1**

- (51) International Patent Classification<sup>7</sup>: **G01F 23/26, G01N 27/02, 33/28**
- (21) International Application Number: **PCT/NO00/00236**
- (22) International Filing Date: **11 July 2000 (11.07.2000)**
- (25) Filing Language: **Norwegian**
- (26) Publication Language: **English**
- (30) Priority Data:  
**19993436 12 July 1999 (12.07.1999) NO**
- (71) Applicant (for all designated States except US): **FORINNOVA AS [NO/NO]; Thormøhlensgt. 55, N-5008 Bergen (NO).**
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **HAMMER, Erling [NO/NO]; Saudalskleivane 66, N-5736 Mjølkeråen (NO).**
- (74) Agent: **AS BERGEN PATENTKONTOR; C. Sundtsgt. 36, N-5004 Bergen (NO).**
- (81) Designated States (national): **AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.**
- (84) Designated States (regional): **ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).**
- Published:
- With international search report.
  - Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **METHODS AND DEVICES FOR MEASURING INTERFACE LEVELS BETWEEN FLUIDS, AND USES THEREOF**



FLOW CHART OF THE MEASURING SET UP IN LABORATORY.

(57) Abstract: A method for measuring interface levels between fluids is described, characterised in that, with the aid of a magnetic field forming means, a variable magnetic field is formed in one of the fluids whereby a counterflowing magnetic field is established, being a function of the fluid properties with respect to the portion of conducting fraction in the fluid, and conductivity of the fraction; and the properties of the mentioned fluid are registered by registering the dominating impedance, alternatively resonance frequency, of the system; and by corresponding registrations of different fluid layers at the respective height levels, and in the existing interphase layers, and thereafter by mutual comparison of the mentioned properties, one or more existing multiphase levels are determined. A device to carry out the method is also described. For measuring concentrations/parts of a first fluid in a second fluid in multiphase mixtures, or in streams of the fluids, further methods and devices are given, including application of these.

WO 01/07874 A1

METHODS AND DEVICES FOR MEASURING  
INTERFACE LEVELS BETWEEN FLUIDS, AND USES THEREOF.

5 The present invention relates to a method and a device for measuring interface levels in separation tanks, and methods and devices for measuring concentrations/parts of a conductive fraction in flowing multi-phase mixtures, and especially where the fluids are immiscible.

10 The inventions have particular relation to the oil industry where immiscible phases of hydrocarbons (oil and gas) and water are being handled, as there may be present salts (give salinity to the water) in the water fraction, and greater or smaller amounts of solid particles, such as  
15 sand. The invention can be applied when one handles flowing mixtures of such fluids and wishes to know relative compositions; or in connection with separation facilities where for example oil and water are to be separated from each other.

20

During production of crude oil, water and gas are separated from the oil onboard the production platforms with the aid of separation tanks that function according to the principle of gravitation. The process water lies at the  
25 bottom of the tank. The next layer is an oil/water emulsion. Then comes crude oil alone, which higher up passes into foam which eventually passes into pure hydrocarbon gas. To optimise the separation process, it is necessary to be able to measure the levels of the different

layers. There are many devices for measuring the height of the different interface levels, but they all have their limitations and only a few can measure the heights of an emulsion layer and a foam layer.

5

It is an aim of the invention to provide a new method and device to measure the levels of the different layers in a separation tank.

10 Furthermore, it is an aim of the invention to provide a new method and device for measuring concentrations/parts of a conductive fraction in flowing multi-phase mixtures, and particularly where the fluids are mutual immiscible.

15 The method and device according to the invention is characterised by the features which become apparent from the characteristics in the respective independent claims 1 and 8, and specified embodiments become apparent from the associated dependent claims 2-7 and 9-11.

20

Furthermore, the methods for measuring concentrations/parts of a conductive fraction in flowing multi-phase mixtures are defined by the characteristics in the independent claims 13 and 14, while the devices are defined by the

25 claims 15 and 16. Preferred embodiments are defined by the associated dependent claims.

According to the invention the following are applied:

- 30 1) device and method according to claims 1-11 for determination of interface layers during separation of oil-, gas- and water phases; and
- 2) methods and devices according to claims 12-17 for determination of the water portion in multiphase mixtures of oil, gas and water, and solid particles (sand).

35 The principles of the invention explained in the following description are illustrated in the subsequent figures, in which:

Figure 1 shows a set-up of the device in the form of a separation tank with the phases (from below) water, oil, and gas, and intermediate boundary layers.

- 5 Figure 2 shows a block diagram of the elements which are part of the detector according to the invention.

Figure 3 shows the measuring curve for the impedance in the coil dependent on the layer in which the measuring probe is  
10 situated.

Figure 4 shows how the invention can be used for connecting level measuring devices for measurement of levels in a container.

15

Figure 5 shows an assembly of an excitation and a detector coil for measuring water fraction in multiphase mixtures.

Figure 6 shows an assembly of two excitation coils and a  
20 detector coil for measuring conductive fluid (water fraction)

Figure 7 shows the results from measurements carried out on a flowing mixture of oil/water/gas by application of the  
25 device shown in figure 6.

#### New measuring principle

A variable magnetic field that penetrates a medium will induce eddy flows in the medium if the medium is  
30 electrically conductive or parts of it are electrically conductive. These eddy flows create a magnetic field which is directed against the imposed field. The counter-induced field will be proportional to the fraction of the conductive components in the medium and the electrical  
35 conductivity of these components.

The magnetic field can be generated by a coil to which current is supplied from an oscillator. The electrical impedance in the coil will then be dependent on the

surrounding medium. The sensitivity increases with the frequency of the magnetic field, but the frequency is limited upwards by the penetrating depth of the field into the medium.

5

If such a coil is placed in a separation tank, the impedance of the coil will be lowest in water and highest in gas. In foam, oil and water/oil emulsions, we will obtain values for the coil impedance in between the mentioned extreme values. In oil-, water-, and gas mixtures it is shown experimentally that the frequency between 5 MHz and 15 MHz will be an optimal compromise between increasing sensitivity and reduction in penetration depth. The frequency is determined by the diameter of the coil and number of windings. Greatest sensitivity is obtained at the resonance frequency of the coil

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where L is the coil inductance and C is the resulting coil capacitance between the windings.

20

As L is inversely proportional to the counterinduced field in the medium and C is dependent on the permittivity of the medium, the resonance frequency  $f_0$  can be used to determine whether the coil is in oil, foam or gas as the capacitance C (but not the inductance L) will be different for each of these layers. Both the coil impedance and resonance frequency will be dependent on the conductivity and droplet size distribution of the conductive components (process water) at the detector coil. But it is the relative change in impedance, alternatively resonance frequency, which gives the different levels in the separation tank. The variations in the water conductivity and size distribution of water droplets in oil (oil-continuous mixture) and the size distribution of oil droplets in water (water-continuous mixture) have, therefore, no influence on the level measurements.

35

Figure 1 shows a diagram of the principle of the measuring set-up in the laboratory in the form of a separation tank/container 10 (typically made of glass) which contains the three phases, water, oil and gas as three separate layers in this order from below, respectively, and intermediate boundary layers. There are two emulsion layers formed between the oil phase and the water phase. The lower of these layers is a water layer 13 with a part of emulsified oil droplets which is designated a water-continuous layer, and an overlaying oil layer 15 which contains a portion of emulsified water droplets which is designated an oil-continuous layer. A measuring probe according to the invention in the form of a coil 12, and connected to an impedance analyser 17, is immersed in the container and the impedance is measured in turn in each of the above mentioned layers.

Figure 2 shows the circuitry of the detector electronics. The circuitry consists of a detector coil 20 containing a capacitance  $C_1$  connected in parallel to a coil  $L_1$ . An amplifier 26 is retro-connected to the coil  $L_1$  and the capacitance  $C_1$ . Furthermore, the coil 20 is connected to a phase detector 22, which in turn is connected to an integrator 24, which in turn is connected to a voltage oscillator VCO.

The oscillator VCO is connected to the retro-connected circuit via a resistance  $R_0$ , and connected directly to the phase detector 22. This circuitry will ensure the excitation of the coil at resonance and make possible the measurement of the impedance of the coil and resonance frequency (at resonance the impedance is pure resistance).

Explanation of Fig. 2.

When the detector coil  $L_1$  is in resonance with  $C_1$ , the retro-connection impedance for amplifier 26 is purely resistive and the phase displacement between  $\omega_1$  and  $\omega_2$  will be  $-180$  degrees. In this case  $\phi_1 + \phi_2 = 0$  and the voltage

from the phase detector 22 is zero. The integrator 24 will in this case have a constant terminal voltage which keeps the voltage-regulated oscillator at  $\omega_2$ . If the detector coil's inductivity changes by the coil being surrounded by a different material, the retro-connected network for the amplifier 26 will introduce a phase displacement such that  $\varphi_1 + \varphi_2$  is different from zero. The phase detector 22 supplies thereby a voltage which is integrated in the integrator 24 and the voltage-regulated oscillator changes the frequency  $\omega_2$  until  $L_1$  and  $C_1$  is in resonance again and thus  $\varphi_1 + \varphi_2 = 0$ . The frequency  $\varphi_2$  will thus be characteristic for the fluid with which the detector coil is surrounded.

Results from the laboratory measurement with the probe connection according to the figures 1 and 2 are shown in figure 3. The measured coil impedance is shown as a function of level in the separation tank ( $N=10$ ,  $f=11$  MHz) ( $N$  is number of windings,  $f$  is the frequency).

From the figures 1 and 3 it will be clear that when the coil is surrounded by process water (e.g. water with conductivity 5 Siemens/meter), the coil impedance is low (ca. 10 ohms). It starts rising at ca. 5 cm because of water droplets in the oil. At 7 cm (in the water/oil emulsion layer) the impedance has risen to ca. 200 ohms to increase to 350 ohms in the oil phase.

Instead of using just one single coil which is manually moved consecutively to the mentioned layers, described above, one can use a submersible rod to which is mounted a number of such coils and which in total covers all the different layers, as shown in figure 1, as will be apparent in the next example.

35

#### The practical arrangement.

With reference to figure 4, a given number of coils 30a, 30b, ..., 30h, (in this example 7 coils) are mounted on a submersible rod, immersed/placed in an enclosed tube 32 by

electrically insulating material. The coil connections in the form of wires are led through the tube 32 to an electronics box (not shown in the figure) placed on the top of the tank 34. A standard electronics multiplexer connects the coils to the detector electronics one by one and the measuring signal from the detector electronics is sent further for interpretation, presentation, information and regulation.

10 The measuring principle used for measuring water fraction in multiphase mixtures.

This measuring principle can also be used for measuring water fraction in multiphase mixtures in which the water component is the only electrically conductive component. In this case, an excitation coil 40 with an oscillator 41 and a detector coil 42 with a voltage detector 43, as shown in figure 5, are used. Both coils 40, 42 are fitted to the outside of a tube of electrically insulating material 44, which carries the multiphase mixture. An oscillator establishes an alternating voltage in the coil for induction of a magnetic field through the tube. The fraction (part) of electrically conductive components in the mixture determines the strength of the induced magnetic field, and thereby the induced voltage in the detector/- measuring coil.

In an oil/water/gas mixture the induced voltage in the measuring coil will be dependent on the water content, but not on the gas and oil content in the mixture, as these two components are not electrically conductive. Today in multiphase flow meters, permittivity measurement and/or gamma absorption measurement are used to determine the fractions in the mixtures. Both these measuring methods are influenced by all three components simultaneously, something which complicates the fraction estimations. The measuring principle presented here makes it possible to measure the water fraction from 0 to 100% water, independent of the amount of the other components in the mixture when these are electrically insulating. The



measurements are, however, affected by the water phase conductivity, but this influence can be eliminated by using the impedance at resonance.

- 5 The droplet size distribution in the fluid mixture will also influence the measurement result, both in water-continuous and water-discontinuous phase. To compensate for this influence, a measurement with a parallel standing excitation coil with a different resonance frequency is  
10 needed. Then we have three independent measurement variables to solve for the three unknown: Conductivity in the water component, droplet size distribution in the fluid mixture and water fraction (water cut).
- 15 The practical arrangement for measuring the water fraction in fluid/gas mixtures.  
The measuring unit for detection of water cut in pipe flows, is for example constructed as shown in figure 6.
- 20 Two excitation coils 50, 52 are wound round an insulating tube 54 (liner) made from an electrically insulating material (such as a so-called peek). Between the two excitation coils 50, 52, a detector coil 56 for the field generated by the two outer coils, is wound round the tube  
25 54. The three coils 50, 52, 56 are mounted inside a coat 58, typically made of steel, and the whole unit surrounds the body (tube/duct) through which the fluid is flowing. The fluid flows preferably from below and upwards, as shown with the arrow 60. The two excitation coils 50,52, are  
30 connected to the excitation coils 62 and 64, respectively, which establish respective alternating voltages with different frequencies  $f_1$  and  $f_2$ , for example such that  $f_1 > f_2$ . Furthermore, the detector coil 56 is connected to a voltage detector 66 which registers the induced alternating  
35 voltage which follows from the induced counter-flowing magnetic field which arises from the water in the flowing oil. The induced voltage in the detector coil is at any time the sum of the induced voltage from the magnetic fields from the excitation coil and thus contains two

frequencies. Amplitudes and frequencies are detected and water fraction and conductivity of the water are estimated with, e.g. the aid of mathematical models or a neural network.

5

If one frequency is used and the resonance frequency for one coil or induced voltage in the detector coil is used, the conductivity of the water must be known. The water fraction and conductivity can vary.

10

By using different frequencies one has two independent equations which can be used to estimate water fraction and the conductivity of the water by use of mentioned mathematical models.

15

Use of one frequency can provide both resonance frequency and impedance which gives two independent variables which also can be used to estimate water fraction and conductivity in the fluid.

20

The experimental results from measurements carried out on a three-component flow rig (oil/water/gas) are shown in figure 7. The figure shows the induced voltage in millivolts as a function of the water fraction in percent.

25

It can be seen that for both the two intermediate phases, water-continuous and oil-continuous phases, the induced voltage decreases when the water fraction increases. The tests, with the measuring points given in figure 7, show the abrupt decline in induced voltage with increasing water fraction at the transition between the water-continuous and the oil-continuous phases. Exactly where the fall occurs is dependent on the direction from which the measurements are taken. Either in the oil-continuous with decreasing water fraction or in the water-continuous with increasing water fraction. Thus, a hysteresis loop is obtained, and this area defines the dividing line between the two boundary layers.

30

35

- The voltage-excitation/detector coils according to the figures 5-6 are included in a larger circuit, such as the one which is used in connection with the figures 1-4, to analyse for impedance/resonance frequency, and where
- 5 comparisons are made with calibrated measurement values, such that one can provide data on the content/distribution of conductive component in the multiphase fluid. Thus one can analyse for fraction of the conductive component.
- 10 The method and device which is described in connection with the figures 5-7, is particularly applicable to measuring conductive component(s) in flowing multiphase mixtures of water, oil and gas. This is relevant during exploration of hydrocarbons from an oilfield or during ordinary transport
- 15 and processing of such mixtures, for example in refineries.

Such flowing mixtures are more or less mixed to emulsions, e.g. oil droplets in water (water-continuous phase) or water droplets in oil (oil-continuous phase), i.e. on a

20 scale between pure water phase and pure oil phase. Over time, the condition in such a mixture will vary.

This means that the method and device, in combination with the use of hysteresis curve presentation as shown in figure

25 7, can be used to find out (with the aid of data processing with mathematical models or neural networks) which type of emulsion that is dominant in the flowing fluid at any time, and where on the mentioned scale the emulsion is lying (in droplets size distribution). Thus, one can all the time

30 monitor and provide information about the condition in the multiphase flow. This is a very important application of the invention, and represents a large step forward for the oil industry.

35 Corresponding methodology is applied to mapping of any occurring transition-emulsions between pure oil and water phases in a tank, such as in a storage tank, as described in connection with the figures 1-4. Thus, one can map

where the transition between oil-continuous and water-continuous phase is lying.

In addition, the invention may be applied to all multiphase mixtures (particularly immiscible mixtures), which contain a mixture of conductive and non-conductive components. For example, generally within the chemical industry, and the food industry, such as during handling of milk, for example during homogenisation where the fraction/part of fat in the milk shall be regulated and emulsified.

C L A I M S

1. Method for measuring interphase levels between fluids, characterised in that
- 5 a variable magnetic field is established in one of the fluids by means of a device creating a magnetic field, whereby a counter-flowing magnetic field is established, being a function of the properties of the fluid with respect to the portion of conductive fraction in the fluid,
- 10 and the conductivity of the fraction;
- and the properties of the mentioned fluid are registered by registering of the system's prominent impedance, alternatively a resonance frequency, and by corresponding registration in different fluid
- 15 layers at various height levels, and in the existing interphase layers, and thereafter mutual comparison of mentioned properties, one or more interphase levels that are present are determined.
- 20 2. Method in accordance with claims 1-2, characterised in that the magnetic field creating means comprises a coil which receives an alternating voltage, such as by means of an oscillator.
- 25 3. Method in accordance with claims 1-2, characterised in that a number of mutually separate coils (30a,30b,...,30h) are being used, arranged in a tube (32) of electrically insulating material, with said tube being arranged in the fluid mixture, the level ratio of which is to be
- 30 registered, and the coils are connected one by one to an impedance analyser/detector electronics via a multiplexer, for further treatment of the measured data.
4. Method in accordance with one of the claims 2-3,
- 35 characterised in that the resulting impedance/resonance frequency (17) is registered from the established counter-induced voltage (magnetic field), depending on which fluid (boundary layer) the respective coil is in contact with.

5. Method in accordance with one of the preceding claims characterised in using a connection is provides for excitation of the coil(s) at resonance including measurement of the coil(s) impedance, comprising:

5 a detector coil (20) comprising a capacitance  $C_1$  connected in parallel with a coil  $L_1$ , an amplifier (26) which is retro-connected to the coil  $L_1$  and capacitance  $C_1$ , and the coil (20) is connected to a phase detector (22), which in turn is connected to an integrator (24) and  
10 further to a voltage oscillator VCO,

and said oscillator VCO being connected to the retro-connection circuit via a resistance  $R_0$ , and connected directly to the phase detector (22),

such that excitation of the coil is ensured at  
15 resonance, and the coil impedance and resonance frequency can be measured, as the impedance is pure resistance at resonance.

6. Method in accordance with one of the preceding claims, characterised in that measurements are carried out at  
20 frequencies up to 20 MHz, particularly in the range 5-15 MHz.

7. Method in accordance with claim 3, characterised in  
25 that the coil resonance frequency

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

for the different fluid phases is measured, with L being the coil inductance and C the resulting capacitance between the windings.

30

8. Device for measuring interphase levels between fluids, characterised by one or more means for establishing magnetic field is/are arranged in order to establish a variable magnetic field in the fluids, and

35 means for registering (17) of the impedance/resonance frequency resulting from the counterinduced voltage

(magnetic field) formed, which depends on which fluid (boundary layer) the respective magnetic field establishing means is in contact with.

- 5 9. Device in accordance with claim 8, characterised in that the magnetic field forming means comprises a coil which can receive an alternating voltage, such as by means of an oscillator.
- 10 10. Device in accordance with claim 9, characterised in that a number of coils (30a, 30b, ..., 30h) are arranged inside a tube of electrically insulating material, with the coil connections being fed to a junction unit which is arranged to connect the coils to the detector electronics one by one, such as an impedance analyser, and the measuring  
15 signal from the detector electronics is sent further for interpretation, presentation, information and regulation.
- 20 11. Device in accordance with claim 10, characterised by a detector connection comprising:  
a detector coil (20) comprising a capacitance  $C_1$  connected in parallel with a coil  $L_1$ , an amplifier (26) which is retro-connected to the coil  $L_1$  and the capacitance  $C_1$ , and the coil (20) is connected to a phase detector  
25 (22), which in turn is connected to an integrator (24) and further to a voltage oscillator VCO,  
said oscillator VCO being connected to the retro-connection circuit via a resistor  $R_0$ , and connected directly to the phase detector (22).
- 30 12. Method for measuring concentrations/parts of a conductive fraction in flowing multiphase mixtures, characterised in that  
an excitation coil (40) and a detector coil (42) are  
35 arranged enclosingly around a body, such as a tube (44), which carries the multiphase volume; the excitation coil (40) is applied an alternating voltage, and the resulting detector voltage registered in the detector coil (44) is compared to calibration values of the system to determine

the part of conductive fractions in the multiphase flow/volume.

13. Method for measuring concentrations/parts of a  
5 conductive fraction in flowing multiphase mixtures,  
characterised in that

the parameters in the form of the conductivity of the  
conducting fraction, size distribution of droplets in the  
fluid mixture and conductive fractions are measured by  
10 application of two excitation coils (55, 57) with  
respective mutually different resonance frequencies  $f_1$  and  
 $f_2$ , and a detector coil (56), and the induced voltage in  
the detector coil (56), which is the sum of the induced  
voltage from the magnetic fields from the two excitation  
15 coils (55, 57), and comprising two frequencies, is applied  
to estimate the independent parameters, such as by means of  
mathematical models or neural networks.

14. Method in accordance with claims 12-13, characterised  
20 in that the method is applied to a flowing mixture of oil,  
water and gas, where the water is electrically conductive,  
while the gas and the oil are not conductive.

15. Device for measuring concentrations/parts of a first  
25 fluid in a second fluid in multiphase mixtures, or in flows  
of the fluids, characterised in that

an excitation coil and a detector coil are arranged  
enclosingly round the volume (such as a pipe which carries  
the multiphase fluid), in that the excitation coil is  
30 arranged to be applied an alternating voltage, and a  
resulting detector voltage is arranged to be registered,  
and the detector voltage is compared to calibration values  
of the system to determine the portion of conductive  
fraction in the multiphase stream/volume.

35

16. Device for measuring concentrations/parts of a first  
fluid in a second fluid in multiphase mixtures, or in flows  
of the fluids, characterised in that



16

two excitation coils (55, 57) which, via excitation oscillators (62, 64) respectively, are arranged to be driven by mutually different resonance frequencies  $f_1$  and  $f_2$  respectively; and a detector coil (56) connected to a voltage detector, with the excitation coils (55, 57) and the detector coil (56) being arranged enclosingly around the volume (such as a tube that carries the multiphase fluid forward).

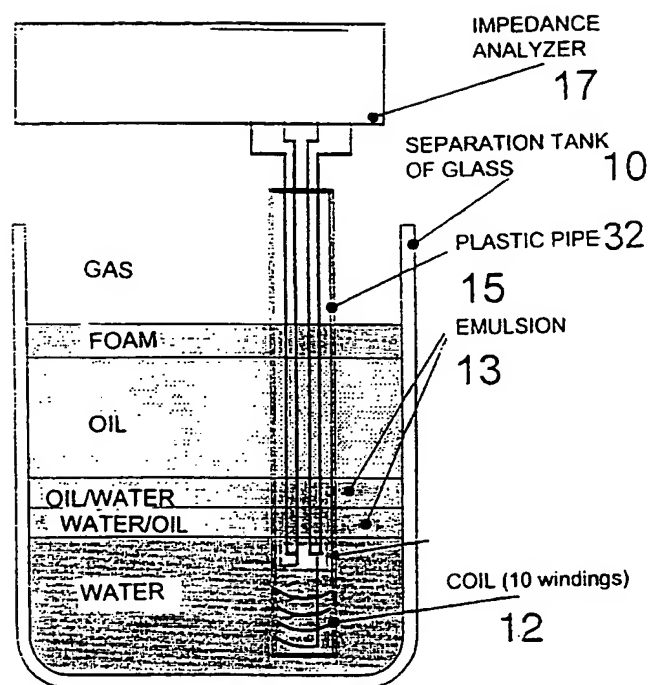
10 17. Device in accordance with claim 16, characterised in that the detector coil (56) is arranged between the two excitation coils (50, 52), and that the unit of the three coils (50, 52, 56) is mounted inside a coat (58), typically made from steel, and the unit surrounds the means  
15 (tube/duct) through which the fluid is flowing.

18. Application of

1) device and method according to claims 1-11 for determination of interphase layers during separation of  
20 oil, gas and water phases; and of  
2) methods and devices according to claims 12-17 for determination of the part of water in multiphase mixtures of oil, gas and water and solid particles (sand).

25 19. Application in accordance with claim 18 for measuring/registering of interphase layers which comprise an oil-continuous layer with a droplet size distribution of water in the oil, and a water-continuous layer with a droplet size distribution of oil in the water, and where  
30 the boundary layer between the oil phase and the gas phase comprises a foam layer.

1/7

**FIG 1**

FLOW CHART OF THE MEASURING SET UP IN LABORATORY.

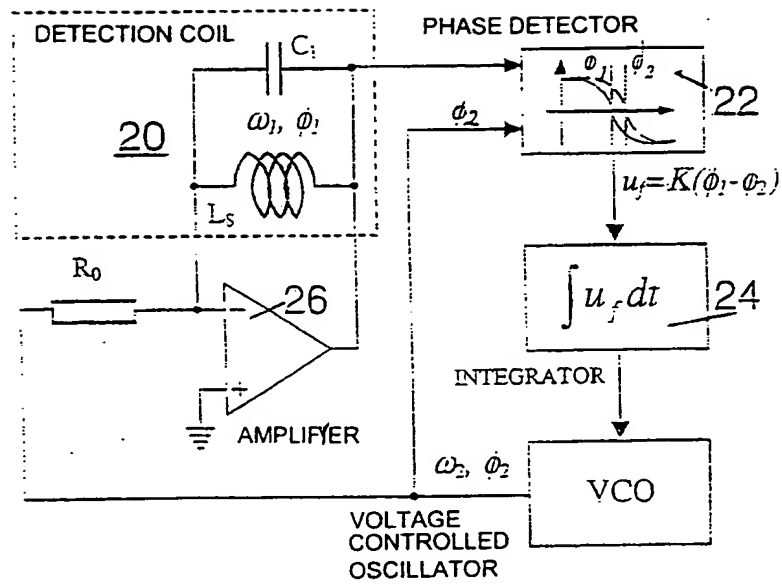
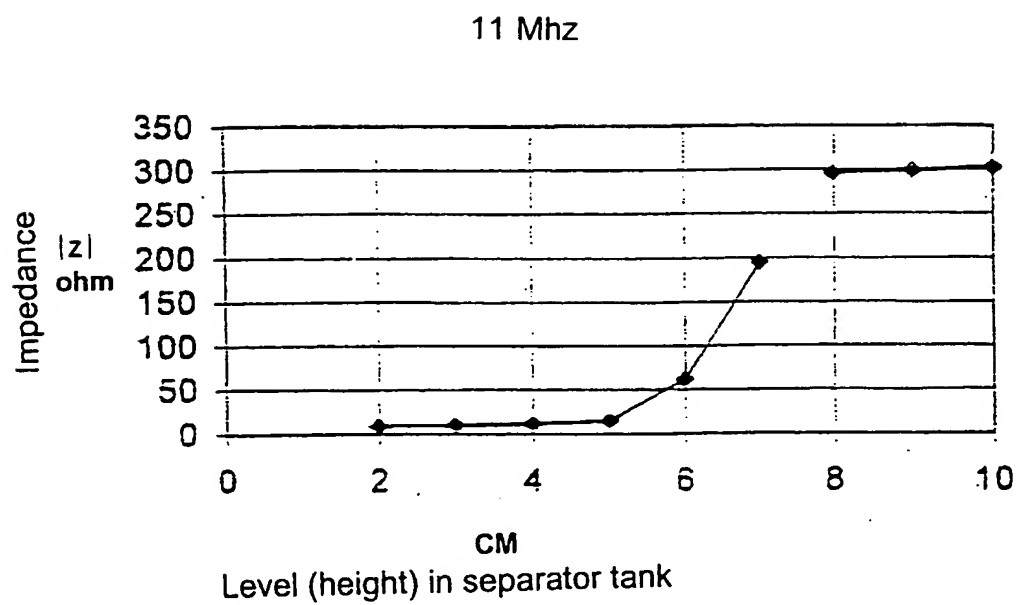


FIG 2  
BLOCK DIAGRAM OF DETECTOR ELECTRONICS

3/7



**FIG 3**  
COIL IMPEDANCE AS A FUNCTION OF LEVEL IN SEPARTOR TANK  
(N=10, f=11 MHz)

4/7

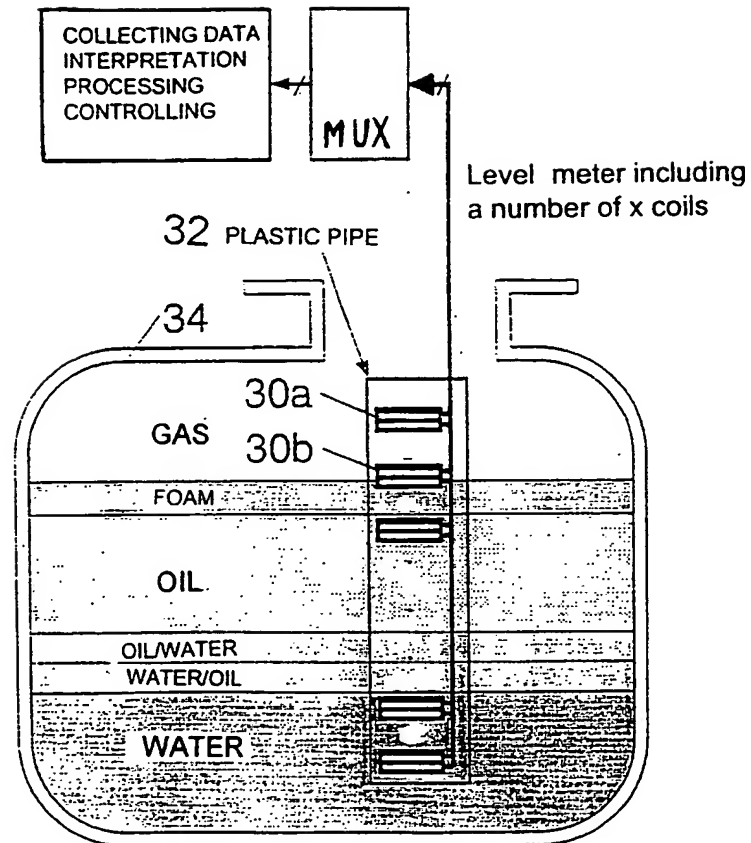
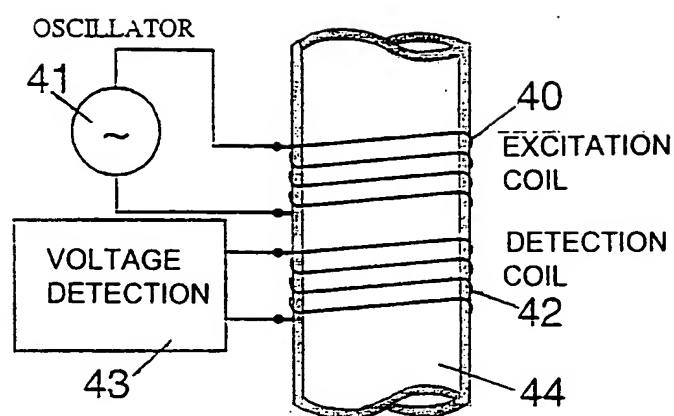


FIG 4

FLOW CHART OF EQUIPMENT FOR LEVEL MEASURING.

5/7



**FIG 5**  
PRINCIPLE FOR METERING  
WATER CUT IN MULTIPHASE MIXTURES.

6/7

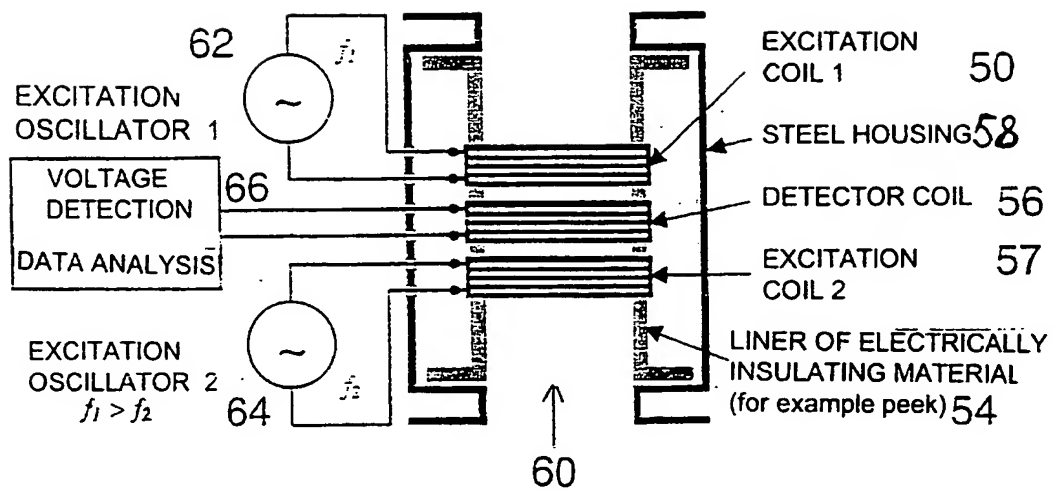
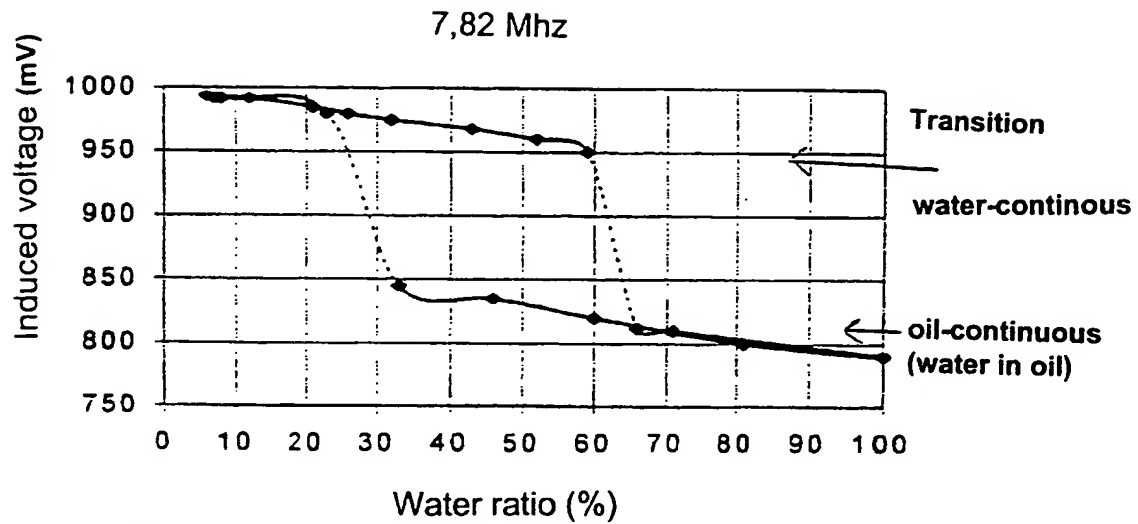


FIG 6

7/7



**FIG 7**  
RESULTS OF MEASUREMENTS FROM  
A THREE-PHASE FLOW RIG OF OIL/WATER/GAS.



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 00/00236

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01F 23/26, G01N 27/02, G01N 33/28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01F, G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SE 399962 B (INSTITUTET ELEKTROSVARKI IMENI E.O.PATONA AKADEMII NAUK), 6 March 1978 (06.03.78), page 3, line 10 - page 4, line 30, figure 4	1,2,4,8,9
Y	--	3,5,6,7,10,11
Y	US 4165641 A (D.I.POMERANTZ ET AL), 28 August 1979 (28.08.79), column 2, line 32 - column 4, line 14	3,5,6,7,10,11
X	NO 19980070 A (ABB RESEARCH LTD.), 8 July 1999 (08.07.99)	1,8

☒ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search	Date of mailing of the international search report
18 December 2000	21 -12- 2000
Name and mailing address of the ISA: Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer  Gunnel Wästerlid /MN Telephone No. +46 8 782 25 00

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 00/00236

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SU 1696885 A1 (SIND-I)SINDYAEV YU I)19911207 (abstract)World Patents Index (online)London,U.K.:Derwent Publications,Ltd. (retrieved on 2000-11-07).Retrieved from: EPO WPI Database.DW 199238,Accession No.1992-314677  --	1,8,18.1,19
X	JP 11006755 A 19990112 ((YOKG) YOKOGAWA DENKI KK (abstract)World patents Index (online).London, U.K.:Derwent Publications,Ltd.(retrieved on 2000-11-07).Retrieved from:EPO WPI Database. DW 199912.Accession No. 1999-137596  --	1,11,18.1, 19,
X	US 4816758 A (WOLFGANG THEISSEN ET AL), 28 March 1989 (28.03.89), column 3, line 7 - line 28; column 3, line 63 - column 5, line 42	12,13,15,16, 17
Y	--	14,18.2
Y	US 5549008 A (CLAUDE BEAUDUCEL ET AL), 27 August 1996 (27.08.96), column 1, line 12 - line 48; column 3, line 1 - line 32; column 5, line 66 - column 7, line 18  --	14,18.2
A	US 4458524 A (RICHARD A. MEADOR ET AL), 10 July 1984 (10.07.84), column 3, line 30 - line 60, figure 5, abstract  --	12-17,18.2
A	US 4367440 A (ROY P. MAZZAGATTI), 4 January 1983 (04.01.83), column 2, line 10 - line 25, abstract  -- -----	12-17,18.2

# INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/NO00/00236**

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

**See next page**

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☒ No protest accompanied the payment of additional search fees.

**INTERNATIONAL SEARCH REPORT**

International application No.  
**PCT/NO00/00236**

The application contains two independent inventions, namely:

Invention 1, claims 1 - 11, 18.1, 19.

A method and an apparatus for determining interface levels between fluids and use of the method and apparatus during separation of a gas-oil-water mixture. A magnetic field is induced in the fluids and impedance or resonance frequency, which depends on the characteristics of each fluid, is measured. From the different measurements the interfaces of the fluids can be determined.

Invention 2, claims 12 - 17, 18.2.

A method and an apparatus for measuring the concentration of a liquid in a mixture of liquids, and use of the method and apparatus for determining the amount of water in a gas-oil-water mixture. An AC-voltage is applied to an excitation coil and the resulting voltage in a detector coil is measured.

These inventions are not so linked as to form a single general inventive concept. There is no technical relationship among these two inventions involving a corresponding technical feature.

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

04/12/00

International application No.  
PCT/NO 00/00236

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
SE	399962	B	06/03/78	SE	7315760 A	22/05/75
US	4165641	A	28/08/79	AU	8192875 A	16/12/76
				BR	7503696 A	29/06/76
				CA	1070409 A	22/01/80
				DE	2526860 A	05/02/76
				DK	265975 A	18/12/75
				ES	438653 A	16/06/77
				FR	2274903 A,B	09/01/76
				IT	1036307 B	30/10/79
				JP	51033665 A	22/03/76
				NO	752160 A	18/12/75
NO	19980070	A	08/07/99	NONE		
US	4816758	A	28/03/89	AT	47062 T	15/10/89
				CA	1270917 A	26/06/90
				DE	3439369 A,C	30/04/86
				DE	3573545 D	00/00/00
				EP	0198910 A,B	29/10/86
				SE	0198910 T3	
				JP	7041402 B	10/05/95
				JP	62500646 T	19/03/87
				WO	8602583 A	09/05/86
				ZA	8508227 A	25/06/86
US	5549008	A	27/08/96	CA	2111508 A	16/06/94
				DE	69312661 D,T	04/12/97
				EP	0603020 A,B	22/06/94
				ES	2108844 T	01/01/98
				FR	2699281 A,B	17/06/94
				JP	6235710 A	23/08/94
				NO	934580 A	16/06/94
US	4458524	A	10/07/84	NONE		
US	4367440	A	04/01/83	NONE		